TEXTILE RESEARCH

Publication of Textile Research Institute, Inc., and The Textile Foundation

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IN THIS ISSUE

F. S. Blanchard's Report to Members 2

Thirteenth Annual Meeting 8

Growth of Research (Address by C. E. K. Mees) 12

Tendering of Cotton Fabrics 15

Modern Textile Technology 20

Plastic Bonded Cotton Fiber 25

Acid Dyeing of Wool 33

Treasurer's Report 44

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TEXTILE RESEARCH

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VOL. XIII **TEXTILE RESEARCH** NO. 2

Outstanding Features in

This Month's Issue

Thirteenth Annual Meeting

A report of the annual meeting of Textile Research Institute with F. S. Blanchard's report to the members and address by C. E. K. Mees. (See pages 2, 8, and 12.)

Tendering of Cotton Fabrics

The need of developing a cotton fabric better to withstand the effects of laundering and of chemical treatments, is outlined by Lt. Col. Frank M. Steadman. (See page 15.)

Modern Textile Technology

The contribution of electronics alone provides laboratory devices and methods unknown but a few years ago. (See page 20.)

Plastic Bonded Cotton Fibers

A practical method of laying a thin lap of unwoven, parallel cotton fibers affords a means of building laminated plastics of greater tensile strengths and may lead to increased use of cotton. (See page 25.)

Acid Dyeing of Wool

Contributing to a better understanding of the part played by acids in complicated dye baths, are new experiments by Research Associates of the Textile Foundation. (See page 33.)

Fessenden S. Blanchard Outlines Year's Progress Of the Textile Research Institute in

Report to Members

THIS MEETING MARKS the end of the first year of our new co-operative arrangement with the Textile Foundation, which marked a turning point in the development of both organizations, and paved the way for our combined efforts to serve the textile research needs of the armed forces when Pearl Harbor made those needs vital and immediate. I should like to review our progress for the past year, and to discuss our plans for the future. But before I do so, I should like to pay especial tribute to Ed Pickard, who served us ably as executive secretary from the time the new arrangement started in the spring of 1941 to the last week in June of 1942. Ed's tactful and far-sighted guidance during our important period of transition to our new basis of operations got us started off on the right foot, and his retirement from active duties, because of ill health, was a real loss to the Institute. Fortunately, we still have the benefit of his advice as treasurer, and member of the executive committee. I should have hesitated to undertake the job he so well filled if I did not know that I could count on his support.

Before discussing our organization changes and the research work we are doing, I should like to compare briefly our membership status today with what it was before the new arrangement. The figures are:

	Life	Sustaining	Company	Individual	Total
May 14, 1941	2	0	59	169	230
Nov. 13, 1942	2	1	96*	232*	331*

* Includes applications in our hands.

While we have been gaining steadily in membership de-

spite the increase of our company membership dues from $50 to $100, we still have a long way to go to place ourselves on a firm foundation. Our directors have already been asked to aid us in obtaining new company members, and I should appreciate greatly the help of our own membership also. We shall be glad to furnish copies of our circular, telling of our aims and functions, to members who would be willing to help us.

The last year has been a year of organization development and of adjustment to the war program. A year ago our New York organization consisted of two people, with editorship of our revised publication TEXTILE RESEARCH being ably handled on part time by Winn Chase—thanks to the generosity of Doug Woolf and *Textile World*. We now have four in our New York office, including our new full-time editor Julian Jacobs, who started his work on May 1st. We plan to add to our personnel a new man to assist us in the organization and supervision of cooperative research and mill contacts, who will have his headquarters in New York and work closely with us here and with Dr. Harris.

In addition, to our own full time staff, I must add the very important fact that, under the new arrangement with the Textile Foundation, the services of Dr. Milton Harris, with his group of research associates and their very complete laboratory facilities at the National Bureau of Standards, have been made available to us. Dr. Harris is now our director of research as well as director of research for the Textile Foundation. We owe a great deal of thanks both to the Textile Foundation and to the Bureau of Standards, not only for their far-sighted attitude that made this possible, but for the splendid cooperative spirit which is making this plan function successfully.

One of the research staff, Albert R. Martin, has been assigned the important task of building up our research information service, which will have for the prompt use of our members an important collection of existing information on all sorts of technical research problems.

(Continued on page 4)

After a year's experience of our publication TEXTILE RESEARCH, with its new format and policy, a questionnaire was sent out to our members by Douglas Woolf, chairman of our publications committee, asking for frank expressions of opinion on the magazine and on our publications policies. You have already had the results of this questionnaire from Mr. Woolf and of his recommendations for a future policy which will we hope preserve the best features of the old and new magazines and add what is most needed. The transition to an improved magazine will necessarily be gradual, but we hope will be well started by the first of the year.

I should like now to review briefly developments in our research policy and work. Early in 1942 we recognized, as did the directors of the Textile Foundation, that from now on it was up to both of our organizations to concentrate our efforts on textile research war problems. Knowing of the wide variety of questions needing solution—and knowing also that many agencies were already at work on some of these problems, it seemed to us that our first job was to enlist the cooperation of the various branches of our industry, as well as the military agencies, in determining:

(1) What were the most important problems.

(2) What had already been accomplished on them.

(3) How best to organize for further necessary research.

Accordingly, on April 7, 1942, we called a meeting of the heads of twenty-three leading textile associations, including associations having important textile committees. We had a splendid response and decided to call the group thus brought together the "Textile Research War Council." We did not consider it wise or necessary to set up a new formal organization of this group, with officers, by-laws, etc., but rather felt that they could best work through the Textile Research Institute and its officers and facilities. We considered that the relationship of the Council to the Institute might be as follows:

(1) The Council would be a valuable means through which important reports on military problems could be called to the attention of all branches of the industry.

(2) Members of the Council would be very helpful as points of contact for the discussion of problems involving their parts of the industry.

(3) We hoped that the Institute might provide a means through which various branches of the industry could get assistance in the organization of research on their important problems.

The place of the Textile Research War Council may be clarified if the Council is considered, as we intended when we organized it, not as a functioning body, but as an advisory and cooperative group which functions through the Textile Research Institute. If you want to take a matter up with the Council as a whole or with any part of it, we—the Institute's officers and personnel—would be glad to assist in calling the appropriate people together, or in taking it up with them.

It is difficult to list in detail the many ways in which we are assisting in the textile research war program, partly because some of the most important work we are doing must remain confidential. However, here are a few of the jobs on which we are working—and when I say "we" I refer to the Textile Research Institute and the Textile Foundation who, while maintaining their separate organization identities, are uniting their efforts on the war program.

(1) The conservation of wool: Dr. Harris is chairman of the Wool Conservation Committee of three set up by the Quartermaster. A panel on blankets has been organized, including qualified and representative members of the industry, to work on possibilities for conservation of wool and the substitution of other fibers in meeting military needs.

(2) Substitution of cotton rope for manila and sisal: A committee has been set up to deal with this subject.

(3) Possibilities for utilization of high strength cot-

ton yarns in order to obtain lighter weight military equipment without loss in serviceability.

(4) We are working with the Committee on Aviation Clothing: At high altitudes the temperature frequently goes to 40 or 50 degrees below zero, making the problem of maintaining life and efficiency at such altitudes one of our most serious challenges.

(5) Accelerated aging of military fabrics: we are working on the problem of speeding up the tests which measure water and weather resistance and other qualities needed for military fabrics, such as duck, burlap, etc.

(6) Resistance of fabrics to ultra-violet light.

(7) Textile Research Planning Committee. Dr. Harris is a member of this committee of four set up by the Quartermaster, under the chairmanship of Major S. J. Kennedy, who is in charge of the textile section in the Quartermaster's Research and Development Branch.

(8) Technical Sub-Committee on Synthetic Fibers of the Office of the Quartermaster General: This Committee has been set up under the chairmanship of Dr. Harold Smith of A. M. Tenney Associates, our vice-president, to act as a clearing house on rayon problems. It was formed by the Synthetic Fibers Committee, of which one of our directors, Dr. E. R. Schwarz, is chairman. We are cooperating with this committee and the Office of Quartermaster has expressed a wish that its work be tied in closely with ours.

(9) Special SUPPLEMENTS to TEXTILE RESEARCH on military finishing requirements such as the supplements on mildewproofing and water-repellency.

(10) In addition to the above problems directly connected with the war effort we are continuing our cooperative project on warp sizing of spun rayons.

Thus our research activities fall into three main classes:

A. Fundamental and applied research, conducted by Dr. Harris and his staff in their laboratories in Washington.

B. Cooperative research conducted, at least in part, outside of the Washington laboratories—the results for an agreed-upon period of time being available only to the companies cooperating in financing the project.

C. Research information service available to our members and covering the status of existing research on many subjects.

I have outlined the developments of the past year. What of the future? That depends partly upon ourselves and partly upon the industry. If I weren't optimistic about the future I wouldn't be here now. On my recent southern trip in which I visited and talked with the executives and research men in over forty mills, I found an encouraging growth of interest in research and several mills who were starting up laboratories following the example of those research leaders in the south who have already made such splendid progress.

The National Cotton Council and the Cotton Textile Institute, the Southern Textile Association, the National Association of Hosiery Manufacturers, the laboratories and experiment stations of the Department of Agriculture, the textile schools, colleges and Institutes, are all playing important parts in the textile research field—each in its important sphere of interest. We believe that our Institute and the Textile Foundation, while doing research work on each fiber can well serve as a connecting link between all fibers.

There is a great deal of work to be done—more than all of us can do in a long time. We have done and plan to do important fundamental work on each of the basic fibers, and we believe that our experince in one fiber will help us in our work on others. We also plan to organize and supervise studies of mill processing aimed to improve efficiency and reduce costs. Both types of research have a real place and we hope to play an important part in both fields.

(The above is a condensation of the address given by Fessenden S. Blanchard at the annual meeting of members of the Institute held Nov. 13, at Hotel Roosevelt, New York.)

Wide-Spread Interest in Research is Indicated by Large Attendance at

Thirteenth Annual Meeting

EXCEEDING IN NUMBER the record-breaking gathering at last year's meeting was the attendance at the thirteenth annual meeting of the Textile Research Institute, Inc., held this year on Nov. 13th in New York at Hotel Roosevelt. The directors and members meetings, held in the forenoon, were followed by luncheon at which 334 were seated at the tables, and the afternoon technical session taxed the available space in that section of the Grand Ball Room. Members and guests were present from textile organizations throughout the industry.

Guest of honor at the luncheon, Dr. C. E. K. Mees, vice president and director of research of Eastman Kodak Company, Rochester, N. Y. addressed the gathering on the growth of research. Some of Dr. Mees' remarks will be found on page 12 of this issue. Preceding the speakers at the luncheon, F. S. Blanchard, president of the Institute presented Edward T. Pickard with a handsome desk clock and calendar—"with the affection of his friends in Textile Research Institute." Franklin W. Hobbs, president of Arlington Mills and chairman of the board of directors of the Textile Foundation addressed a few words of congratulation to the officers and members of the Institute on their progress and bright prospects for the future. K. J. A. Helder, of W. O. Peake, London clothing manufacturers, gave a brief talk.

Textile research war problems were discussed at the afternoon session which was under the direction of Dr. Milton Harris, and following the speakers was a general

discussion of technical problems in which men in different branches of the industry took an active part.

Following the opening remarks by Dr. Harris, Wm. D. Appel, chief of the Textile Section, National Bureau of Standards in Washington, showed several types of blankets and quilts and gave very interesting comparisons of their relative warmth qualities, with results of heat conductivity tests at the Bureau on fabrics constructed of different classes of fibers.

Lt. Col. Bestor Robinson of the Research and Development Branch, Office of Quartermaster General in Washington, outlined some of the many textile problems of this global war and described the difficulty experienced in providing suitable clothing for men who are obliged to expose themselves in the snow and ice of arctic conditions, the terrific temperature changes of desert regions, and the humidity and heat of the South Pacific. Col. Robinson stated that nature had provided an ideal to aim at in the protective suit she has given to the duck: of ideal warmth, yet light in weight and thoroughly ventilated, and impervious to moisture. The duck can remain comfortable out of doors under all conditions.

Lt. Col. Frank M. Steadman of the Philadelphia Quartermaster Depot paid special attention to the specific problem of improving the resistance of cotton fabrics to tendering. (Col. Steadman's opening address will be found on page 15 of this issue.)

Proceedings of Business Meeting

A change in the by-laws authorizing an increase in the number of directors to a total of thirty was adopted at the morning business session. Directors whose terms of office had expired were re-elected: Wm. D. Appel, Arthur Besse, H. M. Chase, Russell T. Fisher, Ephraim Freedman, H. Grandage and Edward R. Schwarz. New directors, to make up the authorized total of 30, were elected as follows: C. F. Broughton, president of Wamsutta Mills; Charles J. Huber, vice president of U. S. Testing Co.; M. Earl Heard, dean of Philadelphia Tex-

tile Institute; Marland C. Hobbs, vice president of Arlington Mills; J. Spencer Love, president of Burlington Mills Corp.; Albert L. Scott, president of Lockwood Greene Engineers, Inc.; and Charles A. Sweet, vice president of Wellington, Sears & Co.

A condensation of president Blanchard's report to the members is given on page 2 of this issue.

Edward T. Pickard, treasurer of the Institute, presented his report which is given on page 44 of this issue.

Wm. D. Appel, chairman of the technical research committee reported that his committee hopes during the coming months to consider some of the problems submitted to the Institute in the survey made a year ago, as well as others which are likely to become of major importance immediately following the war and it would welcome suggestions about technical researches which should be undertaken by the Institute.

In reporting activities of the economic research committee, Stanley B. Hunt, chairman, said in part: We found that essentially all members of the Committee were engaged actively in textile economic researches directly connected with the war today. The shortage of trained personnel to do other economic research projects, plus the highly necessary technical research projects of the Institute today, was considered.

For these and other reasons, the Economic Committee decided to devote its current attention to an outline of economic research work covering postwar economic problems in the industry. This program is being outlined, and if any members of the Institute have any suggestions the committee would indeed be pleased to receive them.

Report of Publication and Publicity Committee

This was given by Douglas G. Woolf, chairman of the Committee and the report is given in part:

The major job confronting this committee was the preparation, dissemination and analysis of the questionnaire as to reader preference on TEXTILE RESEARCH.

I. Results of Questionnaire: Analysis of the replies showed: 95 percent recommend continued publication of TEXTILE RESEARCH and 74 percent of the total replies prefer the new TEXTILE RESEARCH. The analysis showed that 68 percent of the technicians preferred the new magazine to the old, with 85 percent of the executives expressing preference for the new.

Among the technicians, 64 percent want more detailed and complete articles, and 36 percent prefer relatively brief abstracts. Of the executives, 30 percent want more detailed and complete articles, while 70 percent prefer relatively brief abstracts.

II. Recommendations: In view of the above the following plans are under way to meet as nearly as possible the needs of the members of the Institute as reflected in the results of the questionnaire. It is recognized primarily that two kinds of material have to be supplied: one for technicians and one for executives. Some of these changes have already been put into effect:

1. Continue the publication TEXTILE RESEARCH in its present format.
2. Add more detailed and original scientific articles, in a group and department by themselves.
3. Continue the highlights for executives but keep them also in a section or department by themselves and label this material carefully so as it will stand out as a service for executives.
4. Add as complete an abstract service as possible to the book.
5. Keep economic research articles down to a relatively small percentage and then use only such articles as seem to cry for publication.
6. Omit editorials entirely.
7. Publish supplementary bulletins when the time element is involved and we don't want to wait until the press time for the magazine; otherwise include material in the book itself.

Dr. C. E. K. Mees Predicts Development Of New and Better Textiles Through

Growth of Research

"Research can be considered as organized effort to learn how to do the things you will need to do when you can no longer do the things you do now." This definition of research was given by Dr. C. E. K. Mees, vice president and director of research, of Eastman Kodak Co. in an address delivered at the thirteenth annual meeting of the Textile Research Institute, Inc., held Nov. 13, in New York, at Hotel Roosevelt.

Dr. Mees stated—"The history of business is the history of replacement, and industry must look to the research laboratory for new products to replace present products. Research will add a new page to the back of the calendar for every page torn off the top."

Of the factors which have tended to retard the development of research he cited as the most conspicuous, extreme conservatism on the part of financial interests toward new inventions and methods, also a slow recognition of the fact that men with scientific training and experience—research-minded men—could be found who also had executive ability.

Germany pioneered in this development 40 years ago when she broke away from the precedent of research being strictly within the province of the university laboratories, and placed experienced research men in key positions in industry. Industrial firms were fitted up with research organizations—a most revolutionary move.

A prominent factor in the big development of industrial research in this country in recent years has been the fact that many leading executives within our industrial

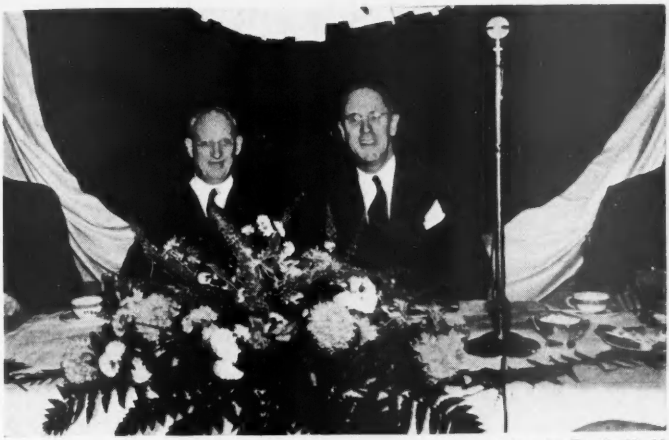


Photo by Textile World

Caught by camera in a jovial mood: Dr. C. E. K. Mees (left) with F. S. Blanchard.

organizations have been drawn from the ranks of research engineers. Heads of research organizations now rank with the other heads of industry, and the importance to industry cannot be overestimated.

Dr. Mees traced the growth of research from the slow beginnings in the prehistoric past, stating that man's knowledge is the accumulated knowledge of the species, but that it was not until 5,000 years ago that the development of the written word and the organization of schools for knowledge gave the first real aid to its dissemination. Development of science, however, was very late in starting, a great handicap being extreme prejudice against any original ideas and methods. Even as late as the Seventeenth Century men fought the acceptance of inductive reasoning, one of the first exponents of which was Bacon.

As recent an example was mentioned as that of Gladstone's skeptical questioning of Farraday, asking what was the possible use of the apparatus he was demonstrating. Farraday, one of the world's greatest experiment-

ers and teachers, replied, "maybe you can tax it." The apparatus in question was the predecessor of the present dynamo and the implications are obvious.

As to the proportion of income that should be apportioned to research, Dr. Mees stated that he had never known of a case of a firm going bankrupt from spending too much on research, but there were plenty of cases where a man had awakened to find a competitor had brought out a product that would supersede his own. The frequent mistake of curtailing research during depressions was pointed out. He said he supposed the limit of appropriation should be the total estimated profit to be made, in the expectation that the value of new discoveries would outstrip the estimates. Anyhow, "although no general rule has been worked out, it should be as much as the industry can absorb."

That research is not an immediate panacea was emphasized. "It will take a new laboratory at least five years to find its feet. It is only when the research staff has covered the existing knowledge that it can begin to search for new. And it will require at least ten years before the research laboratory pays profits." He emphasized the importance of fundamental research saying that "some of the scientific work of today will profoundly affect the world 50 years hence."

Referring specifically to the textile industry Dr. Mees pointed out that although the great changes in that industry due to the advancement of science are coming from without the industry, and although even more fibers with properties hitherto unknown would be forthcoming from the chemical industry; "eventually, the textile industry will do as much scientific work and gain as much from the application of science as any industry in existence and will very rapidly make up for any lag that may have occurred."

Lt. Col. Frank M. Steadman* Presents the Problem Of Lowering the Sensitivty to

Tendering of Cotton Fabrics

THE QUARTERMASTER CORPS presents for your consideration the problem of tendering of cotton fabrics both as a general consideration and a specific problem. As a general consideration it has long been recognized that preparatory and dyeing treatments of cotton fabrics reduce their strength by a degradation of the natural cellulose fiber as it is received from the gin. In general, this tendering of the fiber or the product made from it is not red flagged by the term "tendering." It is accepted simply as a loss in strength in processing, a necessary evil of the cotton textile finishing industry. This tendering of natural cellulosic materials is believed to be actually a degradation of the cellulose molecule, which subject is being studied by a Research Associateship of the Textile Foundation and by others including H. Mark of the Polytechnic Institute of Brooklyn, and R. F. Nickerson of the Mellon Institute. A portion of the work on that subject has been published. It is with that tendering particularly with which we are concerned. It is reported by your Research Associates at the Bureau of Standards that certain types of oxidation predispose cellulosic fibers so modified to further degradation by alkalies in degrees varying with the nature of the original degradation.

The general consideration of this problem which is of interest to all users of cotton textile materials is that the severe laundering treatments to which work clothing and

* Lt. Col. Frank M. Steadman, Philadelphia Depot, Q. M. C. Address at annual meeting, Textile Research Institute, New York, Nov. 13, 1942.

frequently shirts and underclothing are subjected include the use of alkalies and for white goods bleaching materials and sours. These types of chemicals are such that they may cause further degradation of the cellulose. The premise is offered for your consideration that by minimizing the degradation of the natural cellulose fibers in preparation for dyeing and in dyeing and in the scouring and bleaching of white goods, the life of the article may be definitely increased. No corroborating evidence can be offered to this suggestion. It is suggested as a worthy subject for investigation.

Degradation by Impregnating Agents

The specific problem with which the Quartermaster Corps is concerned is an extension of the aforementioned consideration precipitated by this Government's efforts to protect the personnel of the Armed Forces from the vesicant war gases, the best known of which is mustard gas. To afford such protection, certain articles of clothing are impregnated with a chemical agent, necessarily comparatively unstable in order that the reaction may be rapid enough to neutralize any of the vesicant gases which come in contact with the impregnating chemical. This instability causes the release of small amounts of acid which, needless to say, attacks the cellulose. It has been determined that the degree of attack is roughly in ratio to the extent of bleaching to which the fabrics have been subjected. It is probable that no distinction can be made between the effect of bleaching and of scouring, the former having been blamed since it is the more widely variable of the two processes. The scouring, simply, does not usually cause degradation of cellulose to an extent comparable to that caused by the bleaching. Since certain types of degradation predispose such damaged cellulose to further modification and loss of strength when subjected to alkaline solutions, I want to present for investigation the possibility that certain types of degradation may likewise so modify the cellulose as to ac-

Photo by Textile World

Speakers at technical session: left to right: Lt. Col. Frank M. Steadman, Dr. Milton Harris, Lt. Col. Bestor Robinson, and Wm. D. Appel.

celerate attack by acid with resulting rapid and severe tendering.

The Quartermaster Corps has furthermore been directed to increase the depth of color on the cotton herringbone twill, which is procured in large quantities for manufacture into work garments widely used as combat garments. The increase in depth of shade is of itself a dyeing problem. However, to accomplish this increase in depth of shade with adequate penetration of the dyestuff to secure a coloring which will withstand hard wear and repeated launderings, it would be normal to take greater care that a very complete preparation of the fabric was effected, probably extending to and including a thorough bleaching of the goods. This will, it is believed, accelerate the deterioration of impregnated fabrics made from the darker shade herringbone twill.

Two problems present themselves for solution as to possible methods of minimizing this deterioration. First, is the problem of so preparing or so dyeing the fabric that uniform application and adequate penetration of the

dyestuff is obtained without excessive or undesirable degradation of the cellulose. The first step in this is, of course, improved cleaning of the cotton so that less chemical cleaning will be required. Since carding is somewhat of a bottleneck, greater efficiency in the opening and picking operations is highly desirable, followed, however by the most efficient carding practical. With the mechanical cleaning efficiently performed to minimize the bleaching necessary, the next step would be to so scour and finish the goods as to leave it in the most nearly unmodified condition possible. The second possibility is one for which it is feared there is no chance of an immediate or early solution. That is, the use of suitable resin finishes or other types of finishes on materials prepared with as little degradation as can be attained in commercial practice, the finishing materials to protect the fibre from attack by acid or alkaline materials. That is primarily, of course, a problem for the resin industry to work out in conjunction with the textile finishing industry. The entire project is one of immediate and intense interest to the Quartermaster Corps.

Sensitivity to Oxydizing Agents

Another phase of the broad general problem which may be worthy of further investigation or of dissemination of existing information, if available, is the relative sensitivity of mature and immature cotton to attack by oxidizing agents. If there is marked sensitivity to degradation on the part of immature cotton fibre, then it would appear justifiable to consider the practicability of including such requirements, with applicable test procedures, in specifications for fabrics which are particularly liable to severe preparatory treatments and especially to those which may subsequently be subjected to the impregnation previously discussed. Any available information on this matter would be greatly appreciated.

In addition to the intense problem presented by the deterioration caused by the impregnating materials for protection against vesicants, there are other problems

precipitated by changes in special finish requirements and by the substitution of new materials for those long used by the textile industry. One of considerable interest in the first category is that of degradation caused by or which may be caused by mildewproofing and mothproofing agents, the latter of course, being applicable to cotton and wool combination fabrics, or to the application of mothproofing materials to made up garments which are normally sewed with cotton thread. With regard to the special finishes, the problems presented by the application of vinyl resins and synthetic rubber to fabric with the lack of complete knowledge as to any formation of degradation products which might cause tendering are an unknown field. In addition, it may be necessary to combine the application of waterproofing finishes with water repellent and mildewproof finishing materials either by a combination of the two or by superimposing the waterproofing over the other finishing materials, further complicating the possibilities of reactions.

In connection with this general problem, a research project has been initiated to investigate the effect of degradation of cellulose upon future tendering of cotton by certain dyestuffs. That project has just been initiated and is only corrolary to the general problem. It may be of interest to note that the test medium selected was ¾ inch unbleached tape and that the testing, insofar as strength is concerned, will be conducted with the jaws set 1 inch apart in order to minimize any fibre slippage effect.

To summarize, the Quartermaster Corps is interested in practical means of preparing, dyeing, and finishing fabrics with a minimum of damage to cellulose and in setting up adequate procedures by which to insure that a reasonable degree of degradation has not been exceeded. These are of immediate interest and are commended for your attention. Needless to say, the Research and Development Staff of the Philadelphia Quartermaster Depot will cooperate to the fullest possible extent in any investigations which can be undertaken.

New Devices and New Methods for Precise Control Are Employed in

Modern Textile Technology

By EDWARD R. SCHWARZ*

IT HAS BEEN SAID THAT NECESSITY is the mother of invention. Necessity is also the father of modern textile research. It is fortunate that the current interest in textile technology from the theoretical and scientific viewpoint—born of necessity, it is true—comes when it does with highly developed facilities for research in physics, chemistry, biology, mathematics and engineering. The contribution of electronics alone provides laboratory devices and methods unknown but a few years ago. These are the methods which make possible difficult and precise control of mechanisms and of reactions. They release the observer's attention so that it may be devoted to the material under test rather than to the instrument used. They make possible better control of important variables such as temperature, humidity, tension and rate of load application. The photo-cell, the vacuum tube, the high-frequency oscillator, the source of infra-red or ultra-violet radiation, the cathode-ray tube, the sensitive relay, the X-ray generator, the controlled electron beam, and polarized light all represent some form of guided energy. All have places in the modern textile laboratory.

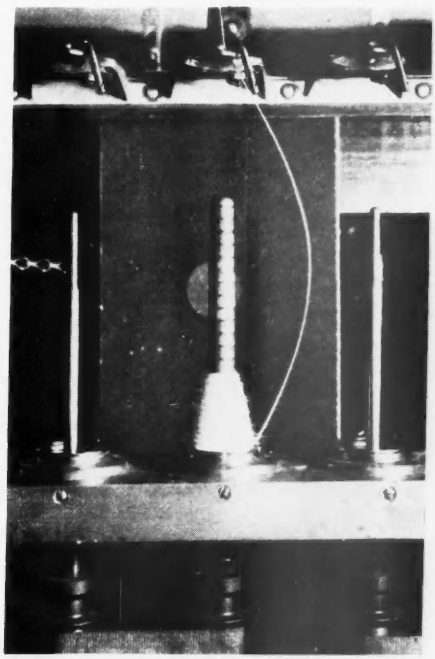
Once a slide rule was so rare as an aid to the textile technician that it was a curiosity. Now for the most efficient use of the powerful methods of the statistician, the textile laboratory requires the fastest and most versatile of electrically operated computing machines. Once the

* Professor of Textile Technology and in charge of Textile Division, Massachusetts Institute of Technology.

light of a north window was ample for all textile examinations. Now all kinds of light—visible and invisible alike—are bent and combined to allow the examination of the most intimate details of fiber structure in the microscope.

Certain molecules can be attached to the structure of the fiber in definite orientation and then made to fluoresce under the action of ultra-violet light. This energy emission is also directional and can be studied with the techniques used for investigations in polarized light to determine minute variations from point to point in the structure of a fiber. It literally lights up what would otherwise be a technical dimout. Fluorescent light itself is greatly simplifying much of the work of photomicrography of textiles. One picture is said to be worth a thousand words. Properly made photomicrographs can be so valuable as to multiply this ratio many fold.

There was a time when textile fibers were something furnished by nature to be combined into yarns and fabrics of beauty and strength for the service of man. So long as they were reasonably strong, flexible and light, they could be satisfactorily manipulated



Stroboscopic light used to photograph a spindle on an experimental spinning frame. (Ordinary camera.)

Ramie fibers in polarized light. The fibers appear in brilliant colors, characteristic of structural conditions and internal stresses.

to form the fabrics suited to the simple needs of a primitive civilization. But with the increasing use of textiles for purposes other than dress, more and more important became the physical and chemical properties of the textile raw materials. Often the resulting goods did not quite suit the purpose and only prolonged cut-and-try investigations eventually brought to light an answer.

Now textiles must meet requirements relating to resilience, powers of insulation against radiant heat, resistance to repeated and rapid flexing, behavior under long continued constant loading, permanence of finish, resistance to abrasion, air permeability, moisture and dye sorption, tear and snag resistance, high ultimate strength, controlled extension and torsion, and proper action under impact. All the pertinent information available from physicist, chemist, botanist, biologist and engineer is required and the modern textile technologist must know where these facts can be obtained; how to use them, and how to interpret the results obtained so that important applications can be made.

It is apparent that we must find out all that we can about the ultimate structure, the architecture if you like, of textile fibers if we are to make intelligent use of them for the satisfaction of our more complex requirements. We must know of what atoms they are composed, how atoms combine into molecules, how molecules build up in

Portion of a single cotton fiber in polarized light, showing the arrangement of fibrils—each of which is made up of oriented chains of molecules.

fiber-like chains, how these chains can be grouped or twisted into fibrils, how fibrils are spun into cells, fibers and filaments, and into the resultant yarns and fabrics by the usual methods of manipulation.

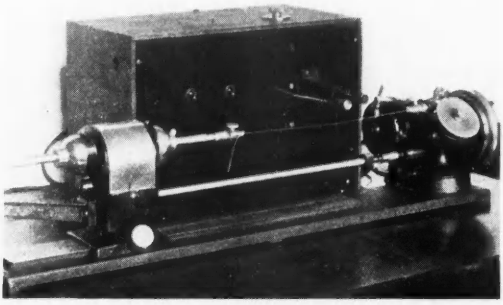
It is important to know why certain fibers behave like intricate combinations of springs and dash-pots when put under tension. It is important to discover what the forces are which hold the chains of molecules together and how they may be altered. It is important to try to discover what nature does in assembling cotton, wool, flax or silk which we have not yet been able to do in assembling our molecular raw materials into rayon, prolon and synthon.

In wartime with every second important and no time to be wasted, we must wage our scientific war with every weapon at our command. Chemical bombs must be devised to tear apart the very structure of the atom and the molecule. Siege guns of energy in the form of heat and light rays must bombard each fiber. A rapid fire of electrons and X-rays must precede the attack of the mathematician and statistician upon the resulting information.

But in textile technology, as in life, we can win the war and lose the peace. The finest scientific investigations are of no practical significance to the industry if they cannot be interpreted into intelligent and active use. If the manufacturer cannot understand the results of the scientist's efforts, these efforts have been in vain. Thus

the crying need is for adequate interpretation and adequate training both for the scientist and for the man in industry. The former must know the problems of the latter and the practical limitations which beset the mill man on every side. The manufacturer must realize the attitude of mind essential to a good research worker, and must make a serious and honest effort to become familiar with at least the simpler language of science. This calls for education. It means the preparation and dissemination of precise information which can be read and understood by all parties concerned. Neither group can longer afford the doubtful luxury of intolerance. Each must respect the other. Each must give as well as take.

The manufacturer of woolen or worsted fabrics can learn much which will be of tremendous value from the technician working with artificial fibers. The research man in the field of synthetics will make faster and more important progress in his work if he utilizes the information modern research is unearthing in regard to the natural fibers. The support of textile research must be active and cooperative—as Vannevar Bush has said: "There is no field in which there is greater opportunity for accomplishment than that of textiles. The key to accomplishment is research. It need not be complex in order to be useful, but it certainly should be intelligent." The intelligent approach is to use the manifold array of weapons for the fight which science is increasingly providing the textile technologist.



Photoelectric controlled, motordriven twist tester for single yarns. (See Textile Research, Vol. 10, p. 120.)

Greater Tensile Strength for Plastics is Indicated By Experiments With Unwoven

Plastic Bonded Cotton Fiber

By M. A. GOLDMAN* AND GERNER A. OLSEN**

The authors have stated that the laying of thin bonded sheets of unwoven fibers has progressed to the practical stage. However the data given in this article are based on early experimentation and are presented at this time in the hope of stimulating additional research on the development of moulded plastic with this type of reinforcement.

ALTHOUGH THE TEXTILE PROCESS was once considered to be fundamentally a fine art for the making of personal goods, an increasing proportion of the consumption of cotton fiber has been used for certain technical requirements and more explicitly for "mechanical fabrics." Furthermore, in certain instances, such specific uses have only been of temporary nature during the interim development of superseding products. A case in point being the automobile tire.

Synthetic fibers have invaded cotton's domain. The use of paper products has made notable inroads on cotton textile consumer goods. Even the fields it now enjoys may be lost, unless it is willing to struggle against these encroachments. If the cotton fiber is to emerge successfully in the coming competition it will be necessary to forget precedent and install new methods of processing

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and fabrication.

Viewed as a structural material, the cotton fiber is comparable in strength to steel. Matthews in "Textile Fibers" page 446, lists a tensile strength for cotton of 37.6 kilograms per square millimeter, which is approximately 53,400 pounds per square inch. Even in this uncompressed state it is not far below the A.S.T.M. specification of 60,000 pounds per square inch minimum for structural steel.

However, as is recognized by various authorities, the tensile strength developed by cotton yarn is only ten to twenty percent of the sum total of the strengths of the individual fibers that, twisted together, form the yarn. Consider the example set by nature in the structure of wood. Here the fibers are in a parallel arrangement bonded by lignin and produce a material as strong as steel when compared by weight, although admittedly not comparable in strength on an equal thickness basis. Moreover, this bonding does develop the full inherent strength of the individual fibers.

It is the purpose of this paper to advance the development and the use of cotton fibers in parallel arrangement bonded by resin, and capable of being molded into structural shapes. This parallel arrangement produces a working assembly wherein each fiber will be in equal tension, and theoretically should secure from cotton four to five times the strength obtained from its present spun and woven assembly. Research already conducted indicates that it may be possible to reinforce the automobile tire with properly integrated and tensioned single fibers instead of stretched coils of fibers such as spun yarn twisted into cords.

In the process of laying parallel fibers only the conventional cotton preparatory machinery is used. Carded sliver is first introduced to the sliver lapper (not shown). It has proved a good practice when 12 ends of 83 grain sliver are drawn 2 to 1 to form a sliver lap weighing approximately 500 grains to the running yard. Four rolls

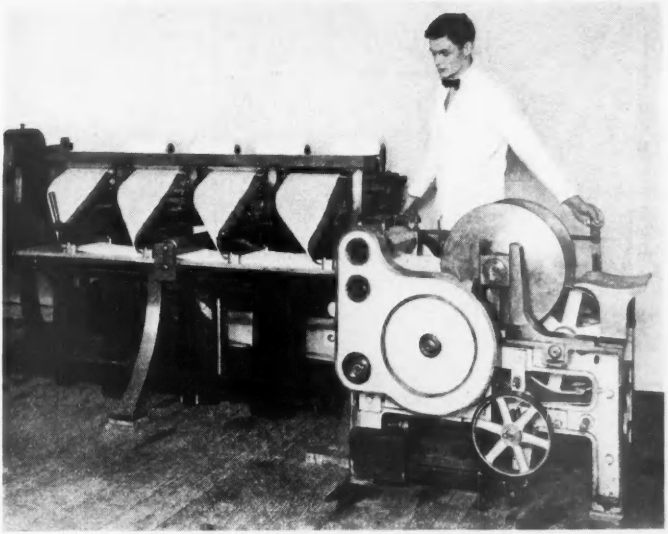


Fig. 1. Conventional four head ribbon lapper, drawing lap of parallel cotton fibers for use in plastic bonded sheets and structural shapes.

from the sliver lapper are then passed through a 4 head ribbon lapper (Fig. 1), under a 4 to 1 draft, condensing to a 500 grain ribbon lap.

The ribbon lap roll is then introduced to the drawing frame (Fig. 2), where it is drawn 4 to 1 and widened to 18 inches, the lap now weighing 125 grains to the running yard 18 inches wide. This passes between the impregnating rolls (Fig. 2), where it may be bonded with such resins or adhesives as may be required by the ultimate product. The thickness and weight of the lap may also be varied, as desired to meet specifications.

These impregnated sheets form the units for laminated assemblies just as do sheets of plywood, paper or woven fabrics. The purpose of these extremely thin laminations is to enable the product to be proportioned with as high as 75 percent fiber and only 25 percent of

the bonding material. The strength of the ultimate material increases with the percentage of fiber present.

Full strength of a tensile member is only attainable when it is perfectly straight, with the applied load acting along its longitudinal axis. In many cases of plastic reinforcement little or no thought has been given to this very important fact. This, of course, may be due to inability to place the reinforcement in the desired direction. Short fibers are rather difficult to handle. The wet laying process is not sufficiently developed at the present time to permit the fibers to be placed parallel to one another. Reinforcement with a woven fabric has a further defect due to the fabric stretching before taking up its full load. The failure to place the reinforcement in the proper direction has, up to the present time, resulted in comparatively weak efforts to strengthen plastics.

It is possible with this material as herein described to place the cotton reinforcement in whatever direction the principal tensile stresses act. The fibers are long enough that, when covered with a thin coating of plastic and bonded with other fibers, they develop sufficient surface shearing strength to attain a maximum tensile resistance. For this reason there is a reasonable assurance that every cotton fiber takes its proportional part of the entire load.

It has been asserted that present day cotton reinforced plastics have been developed with an ultimate tensile strength of 30,000 to 40,000 pounds per square inch. However, information from reliable sources seems to indicate that an actual tensile strength much in excess of 12,000 pounds per square inch cannot be expected from the usual laminated and molded plastic reinforced with *woven* cotton fabrics.

Tests of plastics constructed of fibers laid in parallel arrangement indicate the possibility of exceeding an actual tensile strength of 40,000 pounds per square inch and have a further advantage of simplicity and low cost construction.

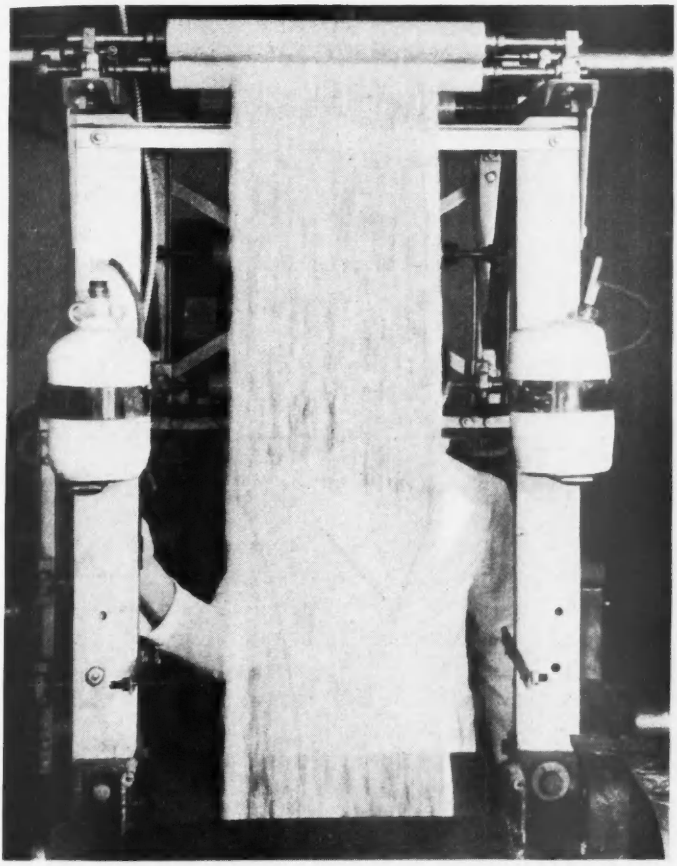


Fig. 2. Final drawing of thin lap of parallel cotton fibers. Impregnating rolls shown at front deliver a bonded sheet ready for building molded laminations.

It is interesting to compare the strength of cotton fiber bonded with plastic and the strengths of some of the common materials. Particular attention is called to the figures in the right hand column in Table I, which show the comparative tensile strengths when figured on a basis of unit specific gravity.

TABLE I. Tensile strength of plastic bonded cotton fiber compared with some common materials.

	Ultimate Tensile Strength in lbs. per sq. in.	Specific Gravity Dry	Ultimate Tensile Strength per Unit Specific Gravity lbs. per sq. in.
Normal Plywood *			
Birch or Beech	13,200	0.67	19,700
Spruce	10,670	0.43	24,800
High Density Plywood * Birch (Compressed to 1500 lbs. per sq. in.)	28,490	1.36	21,000
Steel, Heat Treated *	150,000	7.75	19,300
Duraluminum	54,000	2.81	19,250
Plastic Bonded Cotton Fiber	35,000	1.30	26,900

* "Modern Plywood" Thomas D. Perry, Pitman Publishing Co., 1942.

Although in this table, a tensile strength of 35,000 pounds per square inch is used, it is well to bear in mind that all indications available at the present time point to this value as being conservative. With sufficient research, it could undoubtedly be raised to a higher value. Disregarding this possible future development, the ratio presently presumed to be available is comparable, if not better than, many of the now favored materials.

The individual members of structures and frames are usually designed for a required amount of rigidity. To possess this rigidity their so-called stiffness factor E x I must be high. In Table II, a comparison is drawn between the more common materials and the bonded cotton fiber reinforced plastic, calculated on the basis of an equal weight of 0.50 pounds per square foot.

The modulus of elasticity for cotton reinforced plastic used in Table II was assumed to be that for an individual cotton fiber. This assumption is most certainly on the side of safety. It should also be noted that the value used is, in the belief of an eminent authority, rather low. Some reports have indicated values several times greater. In view of the fact that the rigidity factor of cotton reinforced plastic obtained with this conservative

TABLE II. Comparison of plastic bonded cotton fiber with some commonly used materials. Comparison being made on a basis of material of equal weight of 0.50 lbs. per square foot.

	Thickness	Specific Gravity	EI
Aluminum	.0341 in.	2.81	33.1
Steel	.01225 in.	7.75	4.60
Plastic Bonded Cotton Fiber	.0738 in.	1.30	47.5
High Density Plymouth Birch (compressed to 1500 lbs. per sq. in.)	.0706 in.	1.36	49.5

Width—1 inch in all cases

$I = \frac{bh^3}{12}$—Moment of inertia

lbs. per sq. in.

E-Aluminum = 10,000,000
E-Steel = 30,000,000
E-Plywood = 1,690,000
E-Cotton = 1,420,000

modulus compares favorably or surpasses the highest rigidity factors obtainable from common materials used today, is it not reasonable to assume that if a larger modulus is allowable, the usefulness of the resulting larger EI values would open the way for many promising developments?

Computations given in tables III and IV give interesting comparisons between cotton fiber reinforced plastic beams and those made from some of our most common materials. In Table III the strength of a 3 inch steel I beam weighing 5.7 pounds per foot, 10 feet long and loaded at the center is compared to similarly loaded beams of duraluminum, douglas fir, and cotton reinforced plastic having the same length and weight per foot. Similar but larger steel I beam cross sections were used

TABLE III. Comparison of Beams of equal weight per foot.

Material	Section	Wt. per ft.	I/C	Area	Allowable Stress lbs. per sq. in.	Concentrated Load—10′ Span
Steel	3 in. I	5.7 lbs.	1.7	1.64	18,000	1020 lbs.
Cotton Reinforced Plastic	12 in. I	5.7 lbs.	36.0	9.78	10,000	12,000 lbs.
Duraluminum	7 in. I	5.7 lbs.	10.4	4.52	13,000	4,520 lbs.
Douglas Fir	3 in. x 10 in.	5.7 lbs.	39.5	23.6	1,200	1,580 lbs.

TABLE IV. Comparison of Beams of 8 inch Depth.

Material	Section	Wt. per ft.	S.G.	I/C	Allowable Stress lbs. per sq. in.	Concd. Ld. 10′ Span	P/S
Steel	8 in. I	18.4 lbs.	7.75	14.2	18,000	8520 lbs.	1100
Cotton Reinforced Plastic	8 in. I	3.09 lbs.	1.30	14.2	10,000	4750 lbs.	3640
Duraluminum	8 in. I	6.67 lbs.	2.80	14.2	13,000	6160 lbs.	2200
Douglas Fir	2 in. x 8 in.	3.39 lbs.	0.54	15.3	1200	610 lbs.	1130

in computing the data for duraluminum and cotton reinforced plastic to keep the weight uniform.

Table IV compares similarly loaded beams of the same materials all 8 inches deep. The allowable stress for cotton is taken as being about one-third to one-fourth of the ultimate strength.

From the analyses in Tables III and IV it can be easily seen that cotton reinforced plastic is worthy of every consideration as a competitive structural material. It should also be borne in mind that it is vermin proof, waterproof, flame resistant, and acid resistant. These advantages are obtained due to the fact that the cotton reinforced plastic takes on the character of the bonding resin. Inasmuch as there are many bonding resins each with varying properties, the resulting product can be made to conform with different specifications.

In considering strengths of materials certainly the theoretical allowable stresses of cotton dwell within the range of some of our most useful metals. Should these theoretical considerations prove to be correct and if it is possible in practice to approach them, the applications of such a material should be many. Many of the advances in the use of new materials have been due to their high strength-in-relation-to-weight factors. Cotton reinforced plastic, as strong as some metals, and certainly much lighter, seems to offer a material whose usefulness in this respect is worthy of consideration.

New Studies Reveal Action of Complex Dye Baths in

Acid Dyeing of Wool*

By JACINTO STEINHARDT, CHARLES H. FUGITT, AND MILTON HARRIS**

The nature of the attraction of dyes for textile fibers, how the dyes go on, and what makes them stick so that they resist washing should be explained by any theory of dyeing. Such a theory must also be capable of predicting the effect on the transfer of the dye from bath to fibers of such factors as the amounts of each acid, dye, and salt present in a complicated solution—the dyebath. Earlier papers by Research Associates of The Textile Foundation, demonstrated that different strong acids including acid dyes combine with wool to very different extents. This new paper describes experiments that contribute to a better understanding of the more complex equilibria which obtain in more complicated baths.

EARLIER PAPERS demonstrated that the tendency of wool to combine with different strong acids [6, 7][3] differs widely and discussed the bearing of these differences on the theory of dyeing. The differences were interpreted in terms of combination of wool with anions as well as hydrogen ions, the combination with each anion being governed by its own distinct affinity.[4] Numerical

* Full title of paper—"Combination of Wool Protein with Acids in Mixtures, and its Relation to the Acid Dyeing of Wool."

** Research Associates of Textile Foundation, Milton Harris, Director of Research Textile Foundation and Textile Research Institute, Inc.

[3] Figures in brackets indicate the literature reference at the end of this paper.

[4] The use of the term "affinity" in discussions of dyeing is often ambiguous because two different meanings have been attached to it. In the

values of these affinities (expressed as reciprocals of dissociation constants), for 33 strong acids were tabulated elsewhere [7].

The earlier work, which was limited to studies of individual acids, has now been extended to include an investigation of the combination of wool with acids present in mixtures. The new experiments contribute to an understanding of the more complex equilibria which obtain in mixtures [3] and should be more pertinent to the process of dyeing in complicated baths than were the simpler experiments. The results also contribute to an understanding of the part played in the dyeing process by acids, and by such commonly used assistants as Glauber's salt.

Experimental Procedure

Methods of purification of the wool, measurement and interpretation of pH values, determination of the amounts of acid bound, and application of corrections for the effects of hydrolytic decomposition of the fibers at high temperatures and high acidities, have been described in earlier publications [4, 5, 7].

Each of a number of samples of wool, conditioned at 21° C and 65 per cent relative humidity, was immersed in about 80 times its weight of solution. The solutions contained either the acid form of the dye, Orange II, or its sodium salt. In addition, each solution contained a second acid, either hydrochloric or naphthalene-β-sulfonic acid. Concentrations of dye varied between 0.0004 and 0.025 *M*, while the second acid was present either in equimolar amounts or in amounts 10 times as great.

The solutions were kept at 50° C $\pm$ 0.1° from 3 to 5 days, periods which were shown in earlier work [5, 7] to be sufficient for a close approach to equilibrium. The following measurements were then made on aliquots of each: (a) pH at room temperature, (b) total concen-

present paper the term denotes the extent to which, *under equilibrium conditions,* the ion or acid is associated with the protein. It is not used, as in commercial practice, to describe the rapidity with which dyes combine with the fiber.

tration of acid, by titration, (c) dye concentration, colorimetrically, (d) ammonia produced as the result of hydrolytic decomposition, and (e) in some of the experiments with hydrochloric acid, concentration of chloride by the Volhard method, after decolorizing the solution with hydrogen peroxide. When only acids were present, the amounts of chloride combined with the fiber, calculated from the results of analyses, agreed closely with the amounts calculated by subtracting the amount of dye combined from the total acid combined. Advantage was taken of this agreement to calculate the amounts of naphthalenesulfonic acid bound, since no method for readily and directly estimating the concentration of this ion is available.

Results and Discussion

The experiments to be described fall into three categories: (1) Measurements obtained with mixtures of two acids present in initially equimolar proportions; (2) measurements obtained with mixtures of two acids in initially fixed but unequal proportions, and (3) measurements obtained with mixtures of a salt of one acid in equimolar proportion with the second acid. Data from each group of experiments are represented graphically in Figs. 1, 2, and 3, respectively.[5]

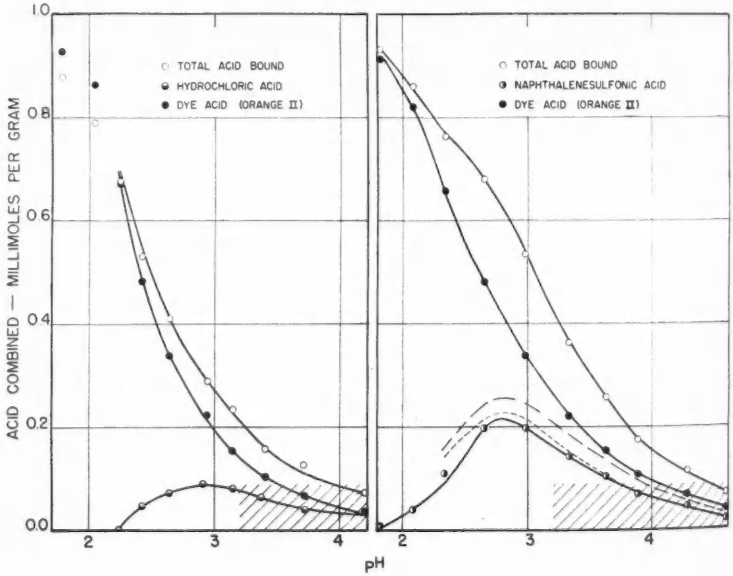
It will be observed that in the experiments with two acids (Figs. 1 and 2) both the total acid and the dye anion combined increase steadily as the acidity increases, while the amount of the second anion combined increases at first, but then diminishes sharply. The maximum amounts of the second anion combined, and the pH values at which these maxima are found, differ in each experiment; they depend not only on the concentration ratio of the two acids but on the specific properties of the second acid as well. Thus, the maximum amount of naphthalenesulfonate combined is considerably larger than the amount of chloride. This is in keeping with relative affinities for wool of these two anions as previously reported [6]. Of

[5] The data on which these figures are based are tabulated elsewhere [3].

the two anions which compete with dye the large naphthalenesulfonate anion competes far more effectively than the smaller chloride ion. The broken lines which follow the course of the curve representing combination with the second anion in certain of the figures have been computed from the respective affinities of the ions involved, as is explained elsewhere [3].

In the experiments with the dye salt (Fig. 3) the more limited supply of hydrogen ion results in the combination of smaller amounts of acid at a given concentration of dye anion than in the other two sets of experiments. Distinctions due to the difference in affinity of the anions are greatly accentuated; thus with hydrochloric acid no detectable amount of the second anion (chloride) combines

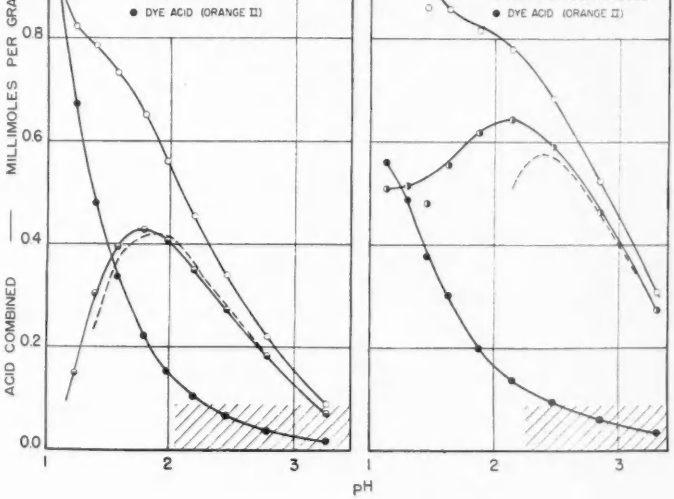
Fig. 1. Total acid, dye acid, and second acid combined with wool at 50° C when dye acid and second acid are initially present in equimolar proportions. Shaded area represents limits of dye combined in ordinary commercial dyeings. Broken curves represent theoretical calculations for the combination of naphthalenesulfonic acid. Upper curve was obtained by method of eq. 4 in another paper [3] and lower curve represents both eqs. 5 and 6 of same paper.



with the wool.[5] Indeed, the affinity of the dye anion is great enough to result in a combination of slightly more dye anion than of hydrogen ion when the supply of the latter is limited. However, when the second anion has a sufficiently high affinity to compete effectively with the dye even under these more severe conditions, the amount of dye bound is smaller than the total acid bound, just as when large amounts of hydrogen ion are available.

In the experiments with the dye salt (Fig. 3) the hydrogen ion concentration and the dye anion concentration were initially equal, just as in experiments with the dye acid alone [6, 7]. However, these initially equal concentrations of hydrogen ion and dye anion are here not necessarily equal at equilibrium, and small differences be-

Fig. 2. Total acid, dye acid, and second acid combined with wool at 50° C when the initial concentrations of second acid are ten times as great as the concentration of dye acid. Shaded area represents limits of dye combined in ordinary commercial dyeings. Broken curves represents theoretical calculations of the amounts of second acid combined, using either eqs. 5 or 6 of another paper [3].



tween the results and those previously reported are to be expected.[6]

Differences in the initial ratio of hydrogen ion concentration to concentration of the colored anion of the dye, which distinguish each set of experiments (Figs. 1, 2, and 3) result in marked differences in the degree of exhaustion of the dye from the solution onto the fibers. The higher is this ratio, the greater is the degree of exhaustion found. Since more acid also remains in the bath at equilibrium, the higher ratios also result in a displacement of the curve of combination of the dye acid in the direction of lower pH values.

However, neither the degree of exhaustion of the dye nor the equilibrium pH obtained with a given initial concentration of dye depends solely upon the ratio of acid to dye. With the same ratio of concentrations of the two anions a higher degree of dye exhaustion is obtained with hydrochloric acid than with naphthalene-β-sulfonic acid. Thus, for example, in the presence of hydrochloric acid, 10.3 per cent of an initially 0.01 M dye solution remains uncombined. When naphthalenesulfonic acid is used, the corresponding figure is 15.1 per cent. Comparable differences appear in the experiments with the dye salt. Even greater differences appear in the experiments with a large excess of acid, where 3.3 per cent of the dye remains uncombined in the presence of hydrochloric acid while a much larger amount, 35.3 per cent, remains uncombined with the same initial amounts of naphthalenesulfonic acid. Differences in the degree of exhaustion of the dye are found even at the same pH and therefore cannot be accounted for in terms of the promotion of dye combination which is brought about by hydrogen ions.

The large differences in the amounts of dye remaining uncombined in the presence of different second anions

[6] The results obtained with mixtures of an acid and a salt depend on maintaining exact equivalence between the amounts of each initially present. The resemblance to the results obtained with acids alone is diminished if this equivalence is not maintained. The extent of this effect is indicated by a single point in Fig. 3, obtained with an initial amount of acid 3 per cent in excess of the amount of dye.

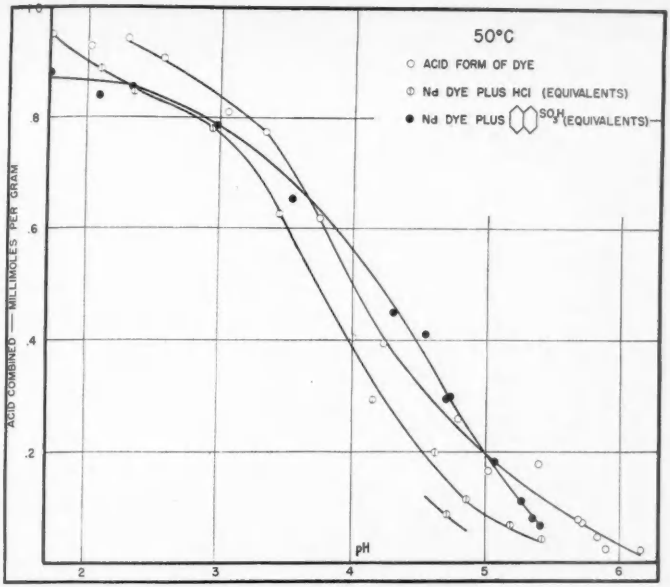


Fig. 3. The amounts of acid combined by wool at 50° C when the sodium salt of Orange II is added in equivalent amounts to either hydrochloric or naphthalene-β-sulfonic acid. The amount of dye acid combined when the acid form of Orange II alone is present is also represented. The significance of the single point which lies on a separate curve is explained in footnote 5.

can be shown by plotting the amounts combined against the negative of the logarithm of the dye concentration at equilibrium. This is done in Fig. 4, in which has been included for comparison data previously published [7] for Orange II alone. As the figure shows, in the presence of a large excess of naphthalenesulfonic acid the quantity of dye uncombined, although small, is approximately 100 times greater than when the same excess of hydrochloric acid is present. Similar but smaller differences appear in the presence of lower concentrations of the second acid. It may be shown that differences such as these are predictable consequences of the anion competition postulated [3].

(Continued on page 40)

Relation of Acidity and Anion Affinity to Level Dyeing

The behavior of wool in acid dyeing is conditioned by the fact that it contains acidic and basic groups, and by the fact that the dye ions commonly involved are anions. Although the anions taken up by the fibers are probably held at or near the RNH^{+}_{3} groups, it need not be maintained that dye would not be combined at all except as the result of this coulombic interaction, or as the result of an acid-basic reaction. In the absence of these factors, dyeing would still be possible since a part of the forces making for the adsorption of the large dye anions would still be exerted. The fiber would acquire a negative charge, and some of the cations present would then be electrostatically bound.[7] However, dyeing behavior would be greatly altered in its relation to concentration of dye, and pH.

The effect of hydrogen ion on the combination of dyes is distinct from that of other common cations, because of the presence of weak acidic and basic groups in wool. Unlike such ions as sodium, hydrogen ion can form a covalent bond with oxygen at carboxylate groups, and is therefore bound to a greater extent. Thus, the addition of hydrogen ion to a solution containing a dye will tend to promote the exhaustion of the dye by increasing the positive charge on the fiber.

It has been shown by the measurements described in the preceding pages that, besides the hydrogen ion, the anion introduced with the acid affects the equilibrium between the wool and dye. The effect of the addition of acid is clearly twofold. The hydrogen ion increases the

[7] Although the forces binding the anion to the fiber may be only in part ionic (coulombic), as is shown by the wide difference in the energy of binding of ions of low and of high affinity [6, 7], the contribution of the ionic energy is very important. The latter exerts an influence over sufficiently great distances to affect the distribution of the ions in solution in a manner favorable to the interaction of the short-range (van der Waal's) forces. These forces operate more effectively when the ions approach the fiber closely under the influence of longer range (coulombic) forces. In the absence of the latter, the amount of non-coulombic association possible would be much reduced and with the smaller ions, might be entirely negligible.

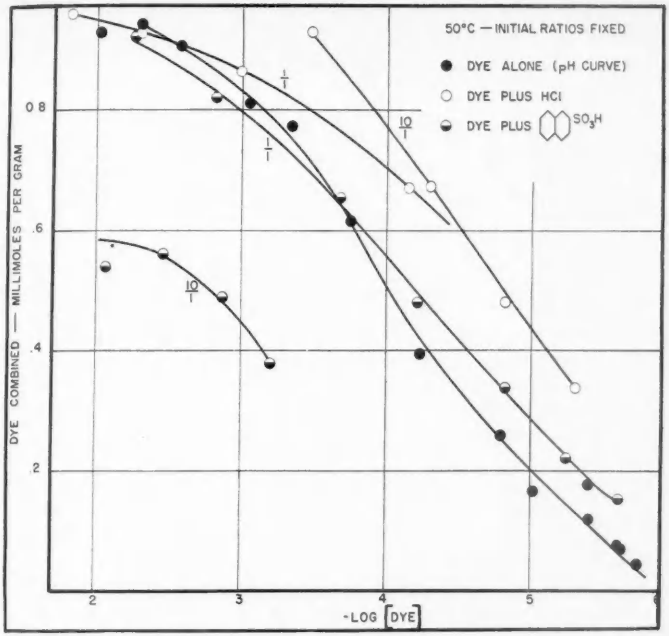


Fig. 4. Comparison of the amounts of dye combined by wool at 50° C at different equilibrium concentrations of dye (moles per liter) when the dye acid is used alone, and when other acids are present in various ratios.

tendency of dye to combine with the wool (as acid) by lowering the pH, just as in all experiments previously reported. There is, however, a tendency of the anion of the second acid itself to combine with the wool. By thus competing with the anion of the dye, the anion of the second acid reduces the increased exhaust which is due to the addition of excess hydrogen ion. Indeed, if the tendency of the second anion to combine is sufficiently great, its competitive effect may nullify and even reverse the tendency of the hydrogen ion to promote exhaustion of the dye onto the fibers. With hydrochloric acid the exhaustion-promoting effect of the hydrogen ion far outweighs the competitive effect of the chloride ion. With

naphthalenesulfonic acid in excess the opposite is true; combination of the wool with its anion occurs to so great an extent that combination of the fibers with the dye anion is greatly reduced (Fig. 4).[8]

Anions other than the dye may also affect the results obtained in acid dyeing in another way. When the acid form of Orange II is used alone [6, 7], the fibers always appear to be dyed uniformly. Microscopic examination of cross sections show that the fibers are dyed "solidly" as (i.e., uniformly throughout their cross-section) as well. The same uniformity and solidity of dye distribution are obtained when either high or low concentrations of naphthalenesulfonic acid are also present. However, when hydrochloric acid is used the fibers are dyed very unevenly and lack solidity. In general, an unlevel dyeing usually results under conditions which lead to combination with a very high percentage of the dye initially present in the bath, that is, to a high degree of exhaust.

If it is considered that even carefully selected and purified fibers such as those used in the present work lack uniformity, not only with respect to size of cross section but also with respect to previous history, the correlation between unlevel dyeing and high exhaust may be understood. Differences between fibers, or parts of fibers, are known to result in large differences in the *rates* at which dye is taken up. Under conditions favorable to a high degree of exhaust, the parts of fibers which dye quickly are soon heavily dyed, and other parts of the fibers can only be lightly dyed or are not dyed at all. At equilibrium, the dye would probably be distributed uniformly, but the rate at which a redistribution may take place is greatly limited by the low concentration of dye in the bath, and extremely low tendency for dye to dissociate from the more highly dyed portions. By keeping the hydrogen ion concentration low, or by providing large quantities of a second anion which reduces the extent of combination of the dye, one may increase the tendency for heavily dyed fibers to dissociate dye into the solution. Redistribution of dye can then occur relatively rapidly.

If this interpretation is correct, it follows that level

[8] Similar competitive effects have been demonstrated in the effect of various salts on the adsorption of acids by charcoal [1].

dyeing will in general be promoted by the presence of colorless anions having a relatively high affinity for the fiber, and which therefore compete effectively with the dye. The sulfate which is usually added to dyebaths, in the form of Glauber's salt, must be expected to have the leveling effect just described. The affinity of sulfate for wool is only slightly lower than that of naphthalenesulfonate and is very much greater than that of chloride. Nevertheless, work as yet unpublished has shown that naphthalenesulfonate presents some advantages over sulfate as a leveling anion in the acid dyeing of wool, especially when dyes are employed with which it is difficult to achieve level or solid effects. While many factors enter into the choice of a leveling agent, such as effectiveness in wetting, penetration of fabrics, dispersing of the dye, and cost, the present studies indicate that the best choice aside from these factors may depend on affinity of the dye employed; with dyes of relatively low affinity, no better competition is needed than that now afforded by the addition of Glauber's salt. Indeed, too effective competition by anions of high affinity would lead to resistance to dyeing, uneconomic exhausts, and a reduction of the washfastness of the dye. However, with dyes of greater affinity, leveling agents capable of more effective competition than that of Glauber's salt should be expected to improve dyeing, especially of blends of different wools; they should not reduce washfastness if they can be effectively removed by a cold water rinse. Previous studies [7] furnish a basis for selection of such leveling agents.

References

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TEXTILE RESEARCH INSTITUTE, INC.

Treasurer's Report for Fiscal Year Ending Sept. 30, 1942

GENERAL FUND

Receipts:		Payments:	
Balance Oct. 1, 1941..	$ 340.27	Salaries (60% of Total)	$ 4,775.94
Sustaining Memberships	11,000.00	Rent (60% of Total)	810.00
Company Memberships	12,737.50	Travel and Meetings..	1,658.83
Individual Memberships	3,210.00	John Price Jones Survey	2,576.56
Miscellaneous Receipts	610.64	Legal Fees	439.72
Trans. from Perm. F'd	1,166.14	Office Supplies & Exp.	1,861.69
		Office Furniture	1,227.12
		Balance Sept. 30, 1942	15,714.69
	$29,064.55		$29,064.55

RESEARCH MAGAZINE

Textile Foundation ..	$ 6,595.40	Deficit, Oct. 1, 1941...	$ 243.03
Subscriptions	614.75	Editorial Services ...	3,631.00
Advertising	122.50	General Salaries (25%)	1,990.00
Back Numbers, Rep'ts, etc.	209.37	Lancaster Press	2,978.16
		Rent (25%)	337.50
Deficit, Oct. 31, 1942...	2,044.36	Misc. Expense	406.69
	$ 9,586.38		$ 9,586.38

DRYING RESEARCH

Balance Oct. 1, 1941..	$ 436.62	Balance Sept. 30, 1942	$ 436.62

WOOL PROCESSING RESEARCH

Balance Oct. 1, 1941..	$ 692.35	Trans. to Co. Mem. Acc.	$ 300.00
		Dues Refunded	40.00
		Balance Sept. 30, 1942	352.35
	$ 692.35		$ 692.35

WARP SIZING RESEARCH

Balance Oct. 1, 1941 ..	$ 1,458.69	Salaries	$ 3,282.20
Rec. from Co-operators	9,500.00	Travel., Meetings, Misc.	376.72
		Balance Sept. 30, 1942	7,299.77
	$10,958.69		$10,958.69

RESEARCH INFORMATION SERVICE

Textile Foundation ..	$ 1,750.00	Gen. Salaries (15%)	$ 1,194.00
		Office Rent (15%)....	202.50
		Travel., Meetings, Misc.	179.58
		Balance Sept. 30, 1942	173.92
	$ 1,750.00		$ 1,750.00

SUMMARY—Balances as at Sept. 30, 1942

General Fund	$15,714.69	
Drying Research	436.62	
Wool Processing Research	352.35	
Warp Sizing Research	7,299.77	
Research Information Service	173.92	$23,977.35
less: Deficit—Research Magazine		2,044.36
		$21,932.99
Permanent Fund—Balance		$ 1,201.59